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U.S. Army Tactical Weather Support Requirements for Weather and Environmental Data Elements and Meteorological Forecasts

by Richard J. Szymber

ARL-TR-3720 **February 2006**

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14. ABSTRACT
The U.S. Army has stated and validated their tactical weather support and data element requirements over the past 30 years. Over 80 weather and environmental data elements, along with their required accuracies, are required for Army tactical weather support. This report establishes the spatial (horizontal and vertical) and temporal resolutions for meteorological forecasts necessary to satisfy the validated accuracy requirements, based on Army echelons (levels of command). Similar information on resolutions is also provided for the new Army modular forces echelons and unit designations.

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Summary

This report addresses Army tactical requirements for weather and environmental data elements and meteorological forecasts, based upon 30 years of evolving, official weather support requirements that have been stated and validated by all Army proponent Training and Doctrine Command (TRADOC) centers and schools. The TRADOC centers and schools have identified requirements for over 80 atmospheric (meteorological), state-of-the-ground (terrain), state-of-the-sea (oceanographic), and space weather data elements, including data accuracy requirements and critical threshold values and impacts.

This report attempts to establish the meteorological forecast temporal and spatial (horizontal and vertical) resolutions and domains necessary to satisfy the Army's weather and environmental requirements. Temporal and spatial resolutions and scales of meteorological forecast models are suggested for supporting both current Army echelons (from echelons above corps (EAC) down to squads) and future Army modular force (MF) structure and unit designations. Results indicate that approximately 80% of the Army's tactical weather requirements fall within the mesoscale time and space scales, 10% fall within the synoptic scale, and 10% come under the microscale domains.

1. Introduction

Army tactical weather and environmental data element requirements have evolved over the past 30 years, from 1975 to the present (2005). Maintained a dynamic baseline database, these requirements are open to changes and additional validated requirements as submitted to the U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH) or as determined by periodic reviews. The original baseline requirements database (the 1977 Combined Arms Combat Development Activity/Agency (CACDA) Weather Study) was established and validated in 1977 by CACDA, the Army Training and Doctrine Command (TRADOC) proponent for weather at the time (*1*). In 1985, USAIC&FH became the TRADOC proponent for weather in the Army (with the exception of Field Artillery, which is the responsibility of the U.S. Army Field Artillery School (USAFAS)). USAIC&FH undertook a major review of the requirements in 1988 under the overall Intelligence and Electronic Warfare (IEW) Mission Area Analysis (MAA), which resulted in an official validated set of requirements in 1991 (*2*).

In 2000 and 2005, USAIC&FH conducted reviews and a revalidation of these requirements. Over the last 30 years, the TRADOC centers and schools have stated and validated their tactical weather support and weather and environmental data element requirements through the official requirements process (i.e., surveys and meetings/conferences). The list of the TRADOC proponent centers and schools that have participated in this process are listed in table 2 (section 2), along with the date of their last update/validation.

2. Army Weather and Environmental Data Requirements

This report concerns the tactical weather and environmental requirements for the branches of the Army (e.g., Aviation, Corps of Engineers, Field Artillery, Infantry, etc.) and recommended (derived) tactical weather forecast requirements for Army echelons. Only tactical level requirements are represented, the strategic (national and theater) and operational level requirements are not addressed in this study. The TRADOC centers and schools have stated and validated their tactical weather and environmental requirements in the following terms only:

- the essential and desired data elements required
- the data element accuracy required
- the data element frequency required
- the forecast period required
- the forecast update frequency required

- the greatest, estimated distance forward of operating bases that weather and environmental information is required to support operations and systems in a 24-hr period on the battlefield
- the maximum altitude above mean sea level (MSL)

Two significant aspects of these requirements are that the Army has no stated/validated requirements for meteorological forecast temporal and spatial (horizontal and vertical) resolution and no stated/validated requirements with respect to Army levels of command (i.e., echelons). Therefore, this report aims at establishing recommended requirements for these two important aspects of Army tactical weather support.

The Army TRADOC proponents listed in table 1 have identified a total of 82 required weather and environmental data elements. In table 1, these data elements are organized along with the most stringent data element accuracy required, based upon all the TRADOC proponents that required that data element (*3*). Only the most stringent accuracy requirement is listed for each data element, since satisfying the most stringent accuracy requirement also meets all other accuracy requirements for a particular data element. Table 2 provides the Army branches' weather and environmental data requirements for forecast period, forecast update frequency, data element (observation) frequency, horizontal range/scale, and vertical range/scale. The values in table 2 are for the most stringent requirement of each TRADOC proponent.

Table 1. Army weather and environmental data element accuracy.

Data Category/Element	Most Stringent Requirement
Atmospheric Data Elements	
1. Acoustic propagation	Not determined
2. Altimeter setting	±0.03 inHg (±1 mbar or 30 ft)
3. Atmospheric contaminants	Not determined
4. Atmospheric density	±1% of standard ICAO atmosphere
5. Atmospheric transmission coefficient	±1 ratio factor
6. Barometric pressure	±0.03 inHg (±1 mbar or 30 ft)
7. Barometric pressure, profile	±0.03 inHg (±1 mbar or 30 ft)
8. Cloud cover amount	±10% of layer amount
9. Cloud base height	±165 ft (±50 m) SFC to 2 km ±492 ft (±150 m) 2-6 km ±984 ft (±300 m) >6 km
10. Cloud top height	±492 ft (±150 m) SFC to 2 km ±984 ft (±300 m) >2 km
11. Density altitude	±5.5 ft (±1.7 m)
12. Extinction coefficient	±1 ratio factor
13. Humidity, absolute, surface	±10% of actual reading
14. Humidity, absolute, profile	±10% of actual reading

Table 1. Army weather and environmental data element accuracy (continued).

Data Category/Element	Most Stringent Requirement
Atmospheric Data Elements (continued)	
15. Humidity, relative, surface	±5% of actual reading
16. Humidity, relative, profile	±5% of actual reading
17. Icing, aircraft	±1 category (trace, light, moderate, severe)
18. Illumination	± 10% of actual illumination
19. Infrared (IR) Target/Background Contrast	±1 ratio number
20. IR Thermal Contrast Crossover Time	± 30 min
21. Light data	n/a
22. Precipitation, rain, accumulation	±.1 in. (±2.5 cm)
23. Precipitation, rain, rate	±.1 in. (±2.5 cm)/hr
24. Precipitation, snow, accumulation	±.5 in. (±1.27 cm)
25. Precipitation, rate, snow	±.5 in. (±1.27 cm)/hr
26. Precipitation, hail, size	±2 in. (.6 cm)
27 Precipitation, freezing	Any occurrence
28. Precipitation, type	Actual type
29. Pressure altitude	±30 ft (±9 m)
30. Refractive index	±1 ratio factor
31. Solar radiation	±50 w/m^2
32. Stability index	±1 Pasquill category
33. Static electricity potential number	±1 category (low, normal, high, very high)
34. Storms, local (thunder, lightning, tornado) within 10 mi	±1 mi
35. Storms, tropical (hurricanes, cyclones) within 100 mi	±25 mi, position of storm eye
36. Temperature, air, surface	±2 °F (±1 °C)
37. Temperature, air, profile	±2 °F (±1 °C)
38. Temperature, air, upper air	±2 °F (±1 °C)
39. Temperature, dewpoint, surface	±2 °F (±1 °C)
40. Temperature, dewpoint, profile	±2 °F (±1 °C)
41. Temperature, windchill factor	Same accuracies as for wind speed and temperature
42. Temperature, inversion levels	±50 m (164 ft)
43. Temperature, wet bulb globe index	±2 °F (±1 °C)
44 Turbulence, aircraft	±1 category (light, moderate, severe, extreme)
45. Visibility, visible spectrum, surface	±10% of range
46. Visibility, visible spectrum, upper air	±10% of range
47. Visibility, visible spectrum, line of sight	±10% of range
48. Visibility, visible spectrum, restriction/range	±10% of range
49. Visibility, VSBL RNG, optical turbulence	±10% of range
50. Visibility, (seeability) IR-MMW-UV,	±10% of range
51. Visibility, (seeability) IR-MMW-UV, upper air	±10% of range
52. Wind, surface, speed/direction	±5º/5 kn

Table 1. Army weather and environmental data element accuracy (continued).

Data Category/Element	Most Stringent Requirement
Atmospheric Data Elements (continued)	
53. Wind, crosswinds	±5º/5 kn
54. Wind, surface, gust speed	±2 kn
55. Wind, surface, gust spread	±2 kn
56. Wind, upper air, speed/direction	±5º/5 kn
57. Wind, upper air, shear	±10% of vertical/horizontal wind shear component factors
58. Wind, profile	±5º/5 kn
Ground State Data Elements	
1. Flood and river stage	±10% of total accumulation over watershed
2. Ground freeze/thaw depth	±1 in. (±2.5 cm), SFC to depth of 11.8 in. (30 cm)
3. Ice thickness, inland	± 0.5 in.
4. IR target/background contrast	±1 ration number
5. IR thermal contrast crossover time	±30 min
6. Precipitation, snow, accumulation	±.5 in. (±1.27 cm)
7. Precipitation, snow, draft depth	±6 in. (±15 cm)
8. Precipitation, snow, metamorphic state	Actual metamorphic condition
9. Precipitation, snow, Liquid water content	±10% of actual liquid content
10. Soil/ground moisture	±5% of actual moisture content
11. Soil/ground temperature	±2 °F (±1 °C)
12. Standing water/pooling	As observed
13. Temperature, water, inland	±2 °F (±1 °C)
Sea State Elements	
1. Bioluminescence	±10% of actual luminosity
2. High sea state (>6–8 ft)	±1 ft
3. Littoral current	±1.6 mph (±1 km/h)
4. Small watercraft advisory	As provided
5. Surf height	±1 ft
6. Swell direction/height	± 5º/1 ft
7. Temperature, sea surface	±2 °F (±1 °C)
8. Wave periodicity	±10% of actual wave number/s
9. Wave direction/height	±5º/1 ft
10. Sea ice thickness	±.5 in.
Space Data Elements	
1. Ionospheric disturbances	As measured/derived

NOTE: SFC = surface; ICAO = International Civil Aviation Organization; IR-MMW-UV = infrared, millimeter wave, and ultraviolet; and VSBL RNG = visible range.

Table 2. Validated U.S. Army weather and environmental data requirements (1990-2005): most stringent requirement.

TRADOC Proponent School/Center (Army Branch)	Forecast Period (hr)	Forecast Update Frequency (hr)	Observation Frequency	Horizontal Scale/Range (km)	Vertical Scale/Range
Air Defense Artillery (2005)	24	6	1 hr	200+	Sfc to 45,000 ft MSL
Armor (2003)	24[a]	6	3 hr	20+	Sfc to 3,000 ft AGL
Aviation (2005)	24	6	1 hr	AO (not stated)	Sfc to 30,000 ft MSL
Chemical (2004)	24	1	1 min[c]	200+	Sfc to 30 km AGL
Engineer (2005)	24	6	1 hr	100+	Not stated
Field Artillery (2005)	24	6	1 hr	200+	Sfc to 30 km AGL
Health Sciences/Services (1996)	24[a]	6	1 hr	AO (not stated)	Sfc to 30,000 ft MSL
Infantry (2004)	24[b]	6	1 hr	30+	Sfc to 1,000 ft AGL
Intelligence (1990)	24	6	1 hr	200-300	Sfc to 60,000 ft MSL
Military Police (2004)	24	6	2 hr	200	Sfc to 23,000 ft MSL
Ordnance (1990)	24	6	1 hr	AOR	Sfc to 1,000 ft AGL
Quartermaster (2003)	24	3	1 hr	50+	Not stated
Signal (2004)	72	6	1 hr	Division/Corps AO	Not stated
Soldier Support Center (1990)	24	6	1 hr	200+	Sfc to 35,000 ft MSL
Special Forces (1990)	24	6	1 hr	n/a (global)	Sfc to 35,000 ft MSL
Transportation (2004)	24	6	1 hr	500	Not stated

NOTE: The dates are the date of validation and the most recent update by the TRADOC proponent.
AGL = above ground level, AO = area of operations, and Sfc = surface.

[a] Up to 72-hr forecast for hurricanes/tropical storms.

[b] Up to 72-hr forecast for tornadoes.

[c] Frequency = 1 min for wind profile and surface gust, 5 min for temperature and dewpoint profiles, and 10 min for surface gust spread.

3. Army Time and Space Scales

Army commanders consider the battlefield area in terms of the time and space necessary to defeat the enemy force or to complete the assigned mission. Time is the first consideration related to a battlefield area. To convert time into space, commanders must consider the unit's mission and capabilities and the maneuverability, terrain, and capabilities of the enemy. The battlefield environment has two distinct areas that can be expressed in terms of time: the Area of Operations (AO) and the Area of Interest (AI). Although the battlefield AO and AI can be expressed in terms of distance (space) and time, it is difficult to be specific about distances,

because different types of units travel at different speeds; and while distances may vary, time stays relatively constant. The mission times of the AO and AI for each echelon (tactical level of command) are presented in table 3 (*4*, *5*).

Meteorological forecasts are keyed to those areas that encompass the AO and AI time horizons. The geographic area covered by the forecast is directly related to the military operations at each tactical level/echelon. The AO and AI mission times listed in table 3 can be used to determine the geographic coverage required for any forecast and each echelon by factoring in distance. After deciding the geographic coverage, the length of the forecast period and the frequency of forecast updates can be determined for each echelon. Generally, a forecast update every 6 to 12 h is sufficient for the first 24-h forecast period. (NOTE: For Battalion and below echelons, the emphasis is more on 3-hourly or hourly updating of the meteorological forecast (i.e., nowcasting).) The recommended forecast periods (length of forecast) of primary intent and for planning, and the frequency of forecast updates, by echelon, are also listed in table 3 (*6*).

Table 3. U.S. Army AO and AI mission times, forecast periods, and frequency of updates.

Current Level of Command (Command Echelon)	Time of AO (Mission Time) (h)	Time of AI (Mission Time) (h)	Length of Forecast of Primary Intent (h)	Length of Forecast for Planning	Frequency of Forecast Update (h)
Echelons Above Corps (EAC)	≤ 96	>96	48 to 96	7 to 10 d	24 to 72
Corps	≤ 72	≤ 96	24 to 72	5 to 7 d	24
Division	≤ 24	≤ 72	24 to 36	3 to 5 d	*12*
Brigade[a]	≤ 12	≤ 24	24	48 h	6 to 12
Battalion[b]	≤ 3	≤ 12	12 to 24	48 h	6
Company	*≤ 3*	*≤ 6*	*12*	*24 h*	*3*
Platoon	*≤ 1*	*≤ 3*	*6*	*12 h*	*1 to 3*
Squad	*≤ 1*	*≤ 1*	*3*	*6 h*	*1*

NOTE: All red, italic values were estimated by Szymber (*7*); sources for all other values were FM 34-130 (*4*), FM 34-81 (*5*), and FM 34-81-1 (*6*).
[a] Weather support for the Aviation Brigades is the same as for the Corps and Division AO and AI instead of for a Brigade (*5*).
[b] The Battalion AO normally covers out to 5 km from the Forward Line of Own Troops (FLOT) for an AO time of 3 h (*5*).

4. Army Meteorological Forecast Requirements

As previously mentioned, the Army has no weather and environmental data (forecast or observation) requirements for temporal or spatial resolution; it only has a requirement for accuracy. Thus, the only requirement for temporal/spatial resolution is that the observational/forecast model resolutions provide the required accuracy stated. As long as the accuracy requirement is satisfied, the resolutions necessary to make that happen are not a

concern to the Army user. With this idea in mind, various meteorological forecast scales and resolutions were derived that could satisfy the basic Army weather support requirements based on current levels of command (echelons) and on the new, future levels of command (modular force (MF) echelons). This information is presented in tables 4 and 5. Because Army operations span the entire spectrum of meteorological scales and resolutions (encompassing synoptic meteorology and micrometeorology), they are best represented based on Army echelons.

Table 4. Forecast scale and resolution of U.S. Army operations (2005).

Current Level of Command (echelon)	Temporal Scale (Forecast Period)	Temporal Resolution	Horizontal Scale (Forecast Domain) (km)	Horizontal Resolution	Vertical Scale (km)	Vertical Resolution
EAC	*168 h (7 d)*	*24 h*	*1,500×1,500 km*	*100 km*	*Sfc to 30*	*1 km*
Corps	*96 h (4 d)*	*12 to 24 h*	*500×500 km*	*50 km*	*Sfc to 30*	*1 km*
Division	*72 h (3 d)*	*12 h*	*250×250 km*	*25 km*	*Sfc to 20*	*1 km*
Brigade	*48 h*	*6 to 12 h*	*100×100 km*	*10 km*	*Sfc to 10*	*500 m*
Battalion	*24 h*	*6 h*	*50×50 km*	*5 km*	*Sfc to 5–7*	*250 m*
Company	*12 h*	*3 h*	*25×25 km*	*2.5 km*	*Sfc to 2–3*	*100 m*
Platoon	*6 h*[a]	*1 h*	*10×10 km*	*1 km*	*Sfc to 2–3*	*100 m*
Squad	*3 h*[a]	*30 min*	*5×5 km*	*100 m*	*Sfc to 1*	*50 m*

NOTE: Corps AO depth = 300 km and AO width = 100 km (*8*); Division Air AI depth = 240+ km (*4*); and Battalion Defense AI depth = 40–60 km (*8*). All red, italic values were estimated by R. Szymber (*7*). Sfc = surface.
[a] Nowcast period (not forecast period).

Table 5. Forecast scale and resolution of U.S. Army operations (2010).

New Level of Command (MF echelon)	Temporal Scale (Forecast Period)	Temporal Resolution (h)	Horizontal Scale (Forecast Domain) (km)	Horizontal Resolution (km)	Vertical Scale (km)	Vertical Resolution (m)
Army	120 h (5 d)	12	2,500 by 2,500	50	Sfc to 30	1000
Corps	96 h (4 d)	6	1,000 by 1,000	25	Sfc to 20	500-1000
Division	72 h (3 d)	3	500 by 500	5-10	Sfc to 10	500
Brigade	48 h (2 d)	1-3	500 by 500	5	Sfc to 5-10	250
Battalion	24 h (1 d)	1	100 by 100	1	Sfc to 5	100

NOTE: All values were estimated by Szymber (*7*); and Army ≈ UEy, Corps ≈ 3-Star UEx, Division ≈ 2-Star UEx, and Brigade ≈ Brigade Combat Teams and Support Brigades.

Over the next five years, new MF echelons will replace the existing command echelon structure (*9*). The new Army MF unit designations are as follows:

- Armies: The Units of Employment (UEy) will become the Army component of a Joint Major Command and will be referred to geographically.
- Corps and Divisions: The Unit of Employment (UEx) will feature three-star and two-star versions; the three-star UEx will be a Corps and the two-star UEx will be a Division.
- Brigades: The Brigades will consist of Brigade Combat Teams (BCT) and Support Brigades. The BCT will be of three types: Heavy, Infantry, and Stryker. The Support Brigades will be organized into five types: Combat Aviation Brigades, Fire Brigades, Battlefield Surveillance Brigades, Combat Support Brigades (Maneuver Enhancement), and Sustainment Brigades.
- Battalions: The Battalions will consist of Constituent Battalions and Special-Troops Battalions for the BCT and Subordinate Battalions for the Support Brigades.

Additionally, the fielding of the Army Future Combat System (FCS) will present unique, high-technology requirements for weather support and services. The FCS is the catalyst for achieving the Army's Transformation vision of fielding a Future Force by 2010. The mission success of the future Army MF will be extremely dependent on the physical environment and very demanding of weather support.

5. Conclusions

The Army's tactical weather and environmental data requirements span the scales of time and space from the synoptic scale through the microscale. Approximately 10-20% of the Army tactical weather and environmental requirements fall in the synoptic scale (e.g., Transportation), 70-80% fall in the mesoscale (e.g., Aviation, Engineer, and Field Artillery), and 10% lie in the microscale (e.g., Chemical). Thus, mesoscale numerical forecast models are required to satisfy around 70-80% of the Army's tactical requirements (e.g., Division, Brigade, and Battalion), synoptic-scale forecast models are necessary to satisfy about 10-20% of the requirements (e.g., EAC and Corps), and microscale models are needed to handle the remaining 10% of the requirements (e.g., Platoon and Squad). Most mesoscale-size system features of Army interest can be detected and monitored with an optimal surface observation station separation of no more than about 30 to 35 km (*10*); and a surface observation rate as often as every 30 min can provide the necessary density of observations required for Army meteorological forecasts (*11*).

The optimum approach to satisfying the Army's wide-ranging tactical meteorological data elements and weather support requirements involves using a nested grid forecast (with a scaleable, relocatable window) and nowcast models (covering the synoptic scale, mesoscale, and

microscale, as depicted in figure 1) with real-time, in-theater battlefield observations from in-situ and remote surface, upper-air, airborne, and space observing systems. Certainly, the Army's unique, high-resolution microscale requirements, primarily driven by chemical requirements, are the most technically and operationally challenging to satisfy. This report aims to provide helpful information and guidance to the U.S. Air Force and Army weather communities as they work jointly toward satisfying the Army's current and future tactical weather support requirements.

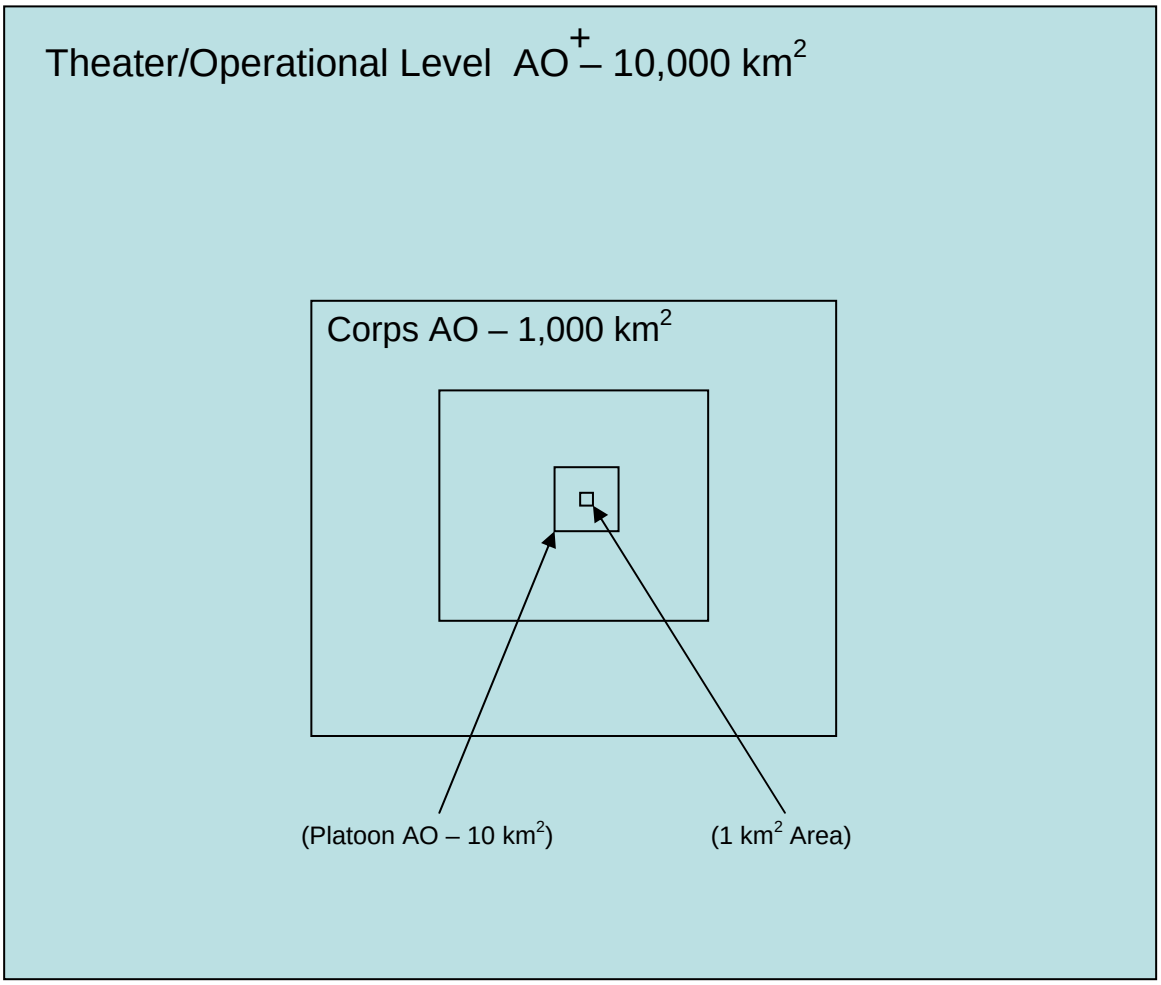

Figure 1. Nested grid model (with a scaleable, relocatable window) concept.

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Acronyms

AGL	above ground level
AI	Area of Interest
AO	Area of Operations
BCT	Brigade Combat Teams
CACDA	Combined Arms Combat Development Activity/Agency
EAC	echelon above corps
FCS	Future Combat System
FLOT	Forward Line of Own Troops
ICAO	International Civil Aviation Organization
IEW	Intelligence and Electronic Warfare
IR	infrared
IR-MMW-UV	infrared, millimeter wave, and ultraviolet
TRADOC	Army Training and Doctrine Command
MAA	Mission Area Analysis
MF	modular force
MSL	mean sea level
SFC, Sfc	surface
UEx	Corps and Division Unit of Employment
UEy	Army Units of Employment
USAFAS	U.S. Army Field Artillery School
USAIC&FH	U.S. Army Intelligence Center and Fort Huachuca
VSBL RNG	visible range

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